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# NIAGARA FALLS:

THEIR

## PHYSICAL CHANGES,

AND

## THE GEOLOGY AND TOPOGRAPHY

OF

## THE SURROUNDING COUNTRY.

**BY JAMES HALL,**

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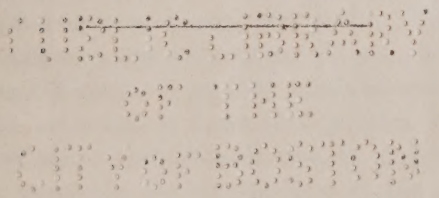
[From the Boston Journal of Natural History.]



From Oph. v. 164
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# NIAGARA FALLS.

The cataract of Niagara and the geology of the surrounding country, have been often described; but believing that there are many facts unnoticed, and others which have not had due weight in these considerations, I shall venture a further attempt at illustrating some important points regarding this great finger post in the path of time. I am far from asserting that the problem regarding the recession or the former condition of this great cascade is settled. So many disturbing causes are constantly presenting themselves, that although the great principles may be deemed established, yet it is impossible to calculate accurately the effect of these minor influences. Every fact recorded of the past, the present, or the future condition of this cataract will aid in the calculation of the final result, which, some thousands of years hence, may be made with tolerable accuracy. In the mean time we must content ourselves with observing these facts and laying down land-marks for the guidance of those who may follow us in the attempt to decide the effect of time upon these ancient rocks.

A striking feature in the Topography of western New York, is the great difference of elevation between the Lakes Erie and Ontario, when taken in connexion with the generally level or but slightly uneven surface of the country, and where there are no disturbances among the strata. The difference of elevation between the other great lakes is comparatively small, although Superior is situated in a disturbed geological region. The elevation of Lake Erie is three hundred and thirtyfour feet above Lake Ontario, and the greater part of the difference is overcome by Niagara river in the space of one mile at the rapids and falls.

The barrier at the outlet of Lake Erie is formed by a terrace of limestone which extends from the Hudson river, west-

ward far into Canada, forming for many miles the northern boundary of the lake. The southern slope of this terrace or platform of limestone passes off beneath the water, forming the bed of the lake. This terrace terminates abruptly on the north, within a short distance of the lake, and we descend into a low, level country, underlaid by marles and shales of the saliferous formation, which extend for a distance of fifteen or eighteen miles. Beyond this, there is an almost imperceptible ascent for eight miles, when it suddenly plunges down about 250 feet, over the outcropping edges of various strata, which here terminate abruptly, to the low table land, bordering Lake Ontario. From the base of this escarpment, the country slopes almost imperceptibly to the level of the lake, seven miles distant, and one hundred and twenty feet lower. A great portion of the country for twenty miles north of the first terrace, or that bordering Lake Erie, is so level that a rise of the Niagara river for thirty feet, would inundate an extent of thirty miles on both sides. After leaving the level country, the ascent, as before stated, is very gradual to the north; but when we arrive at the edge of the great terrace of Lewiston and Queenston, the elevation is thirtyeight feet above the level of Lake Erie. The general outline of this part of the country will be seen in the section from Erie to Ontario.

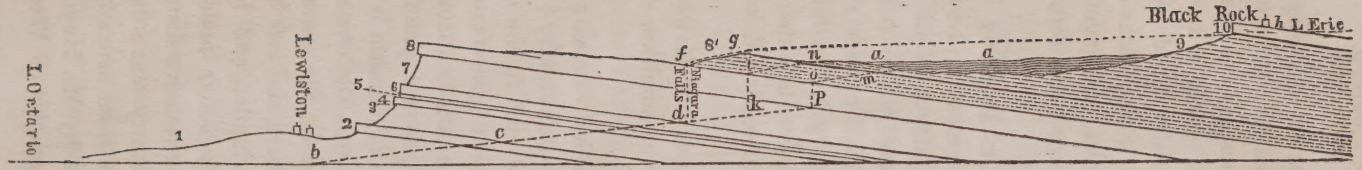
This great terrace or platform is known in New York as the mountain ridge, and in Canada as Queenston heights. It extends to the westward of Niagara river, beyond the head of Lake Ontario, and eastward beyond the Genesee river, where it merges in the general level of the country; partially from the dip of the rocks in that direction, and partially from the thinning of some of its members. The abrupt termination of the various strata in the face of this cliff, prove conclusively the extent of denuding action upon this portion of the country. The basin of Ontario, on the north of the terrace, has evidently been excavated from the sedimentary strata, the limit of denuding agency and that of the lake basin being the line of this escarpment. The edge of this escarpment is indented by numerous ravines or gorges, extending to a great-

er or less distance ; they usually present a broad opening to the north, and terminate at a point within the first mile, and generally within a shorter distance. The streams now flowing in these ravines, evidently had little or nothing to do with their excavation, as the space is partially filled with drift, a deposit from another source. These indentations are doubtless in part the effects of the great denuding agency which produced the escarpment, by undermining and removing the different materials.

It has been supposed by some, and Dr. Daubeny has adopted the opinion, that the terrace or escarpment at Lewiston was produced by a fault ; either an uplifting of all the strata on the south, or a downthrow of those on the north. Not having Prof. Daubeny's paper before me, I cannot state his arguments, but whatever they may be, they are certainly unsupported by facts. The strata are all visible in either direction, and there is no evidence of even the smallest disturbance.

The strata, as they are exposed in the terrace of Lewiston and Queenston, and in the banks of the river on either side, are exhibited in the section on the next page.

There is here not only no evidence of a fault causing the difference in elevation, but direct proof to the contrary ; the soft marl and shale, forming the base of the cliff in the river banks, underlies the plateau from this place to Lake Ontario, and is visible, almost continuously, for the whole distance. On the other hand, there are the most unequivocal proofs of denuding action, and that the whole basin of Ontario is due to the excavating power. It will be seen that the character of the strata is such as to offer great facilities for the operation of such an agent, consisting of alternating hard and soft beds. The action of water would undermine the harder, and leave them to fall by their own weight, while the softer materials were removed. The denudation of such extensive districts, could only have taken place while the country was submerged, and during the period of its elevation from beneath the ocean. This principle has been recognized by Mr. Hayes, in his description of the " Geology and Topography of Western




SECTION OF THE STRATA FROM LAKE ONTARIO TO ERIE.

EXPLANATION OF THE SECTION.

1. Red shale or marle in the bank of the river at Lewiston, and extending to Lake Ontario.

2. Grey quartzose sandstone.

3. Grey shale, like No. 1, with their courses of sandstone near the top.

4. Red and mottled sandstone, a part of No. 8—Grey band of Eaton.

5. A thin mass of green shale.

6. Compact grey limestone,—a member of the "Protean Group"

7. Soft shale, slightly calcareous—*Niagara shale—Rochester shale.*

8 Limestone, compact and geodiferous; Magnesian but not siliceous—*Lockport limestone*—Niagara limestone.

8'. The upper thin bedded portions of the Niagara limestone.

9 Onondaga saliferous group, including the water limestone, or beds of passage to the next mass.

10. Helderberg limestone formation—much thinner than farther east.

*a. a.* Deposit of gravel, &c. south of the rapids. Probably similar to the fluviatile deposit of Goat Island.

*b. c. d. f g. h.* The dotted line representing the surface of the water from Lewiston to Lake Erie.

*d. f.* The perpendicular fall over the Niagara limestone and shale.

*f. g.* The rapids, fiftytwo feet over the upper thin bedded portions of the Niagara limestone.

*c.* The whirlpool.

*i. k.* The position of the falls after a recession of one mile.

*i. n.* The line of the rapids at that time.

*o. p.* The position of the falls after a recession of two miles.

*o. m.* The rapids at the same time.

New York,"* By adopting this mode of explanation, we are enabled to account for the existence of this and similar terraces, along the lines of bearing of our extensive limestone formations, as well as for the deep valleys of ancient origin.

The strata forming the escarpment at Lewiston, as seen in the section, are those through which the chasm of the Niagara is excavated. The whole dip gradually to the south, and all below No. 8, disappear below the level of the river before reaching the falls, as may be seen by the dotted line bed which represents the surface of the river below the falls. The strata above this line are those excavated to form the channel of the river. The limestone forming the summit of the terrace, and at its margin not more than twenty feet thick, gradually increases from the addition of higher layers, till at the falls it has acquired a thickness of one hundred and twenty feet. This limestone, about one mile south of the falls, disappears beneath the surface, and is succeeded by a soft marl of a bluish or greenish grey color, with purple bands. This formation, which is a continuation of the Onondaga saliferous group, occupies all the level country from two miles south of the falls, to Black Rock, a distance of eighteen miles by the course of the river. This is succeeded by the water limestone and Helderberg limestone group. The saliferous formation, occupying this great breadth of country, and forming an important item in any calculation regarding the recession of the falls, has nevertheless always been overlooked by observers, and its existence in that part of the country was never noticed by any one, till the publication of the New York Geological Reports, in 1838. Previously, all the distance between the falls and Lake Erie was considered as underlaid by limestone; and the limestone of Black Rock, or the Helderberg group, was placed immediately above the Niagara limestone, and represented as resting upon it.

The Niagara river, in its escape from Lake Erie, has excavated a passage through the Helderberg limestone, (No. 10,) which forms the upper terrace before noticed, leaving a small

* Am. Journal of Science, Vol. XXXV. No. I.

island, known as Bird's Island, in the midst of the stream. From Black Rock to within two miles of the great fall, the channel is excavated in the rocks of the saliferous group, the descent in this distance being only fifteen feet. About one mile south of the fall, the Niagara limestone approaches the surface, and forms the commencement of the rapids. The current, for the first two miles after leaving the lake, is very rapid ; after this distance, it flows on more gently, the channel gradually widening as far as Grand Island, where it is nearly two miles wide. It then divides, the greater quantity of water running on the west side of this island. There are several small, low islands in the river, above Grand Island, but this is far larger than all of them. Below this island the river expands to a width of two or three miles, and presents all the appearance of a quiet lake with small, low islands. Approaching the rapids, the river narrows, and the current becomes more rapid, and for about one mile before reaching the grand cascade, rushes on with inconceivable velocity, over a declivity of fifty two feet, to the edge of the precipice, where it is precipitated into a gulf one hundred and sixty feet below.

The chasm through which the Niagara river flows, from this point to its emergence into the low country at Lewiston, is excavated in the rocks represented in the section, Nos. 7 and 8 only being visible at the falls, the others rising successively from beneath the water, owing to the declivity of the bed of the river, and the ascent of the rocks to the northward. The sides of this chasm present almost perpendicular walls, with a talus at the bottom, formed by the falling of some of the higher masses. The outlet of this chasm, where the river emerges into the plain at Lewiston, is scarcely wider than elsewhere along its course. In some places the river flows in a channel of less than two hundred yards across, and again is expanded to twice that width. The breadth of the chasm across the top, is nearly twice that of the channel or stream at the bottom. The declivity of the bed of the river, from the falls to Lewiston, is one hundred and four feet, or nearly fifteen feet to the mile, which gives great velocity to the

stream. At one place, however, about a mile below the fall, and where the channel is narrowest, the stream glides along with comparative quiet, while below this, where the channel is broader, it is thrown into great confusion. Again, below the whirlpool the surface of the river is more smooth, and the current more gentle, though the channel is narrower than above. The cause of these appearances, which have seemed inexplicable upon the common theory, and have been used as arguments against the recession of the falls, is to be sought in the geological structure of the place. It will be seen that below the whirlpool there are no hard rocks in the bed of the river, and consequently the channel is deeper than where such rocks exist. At the whirlpool, and above that place, the hard sandstone, No. 2, is at and near the level of the river, and consequently the channel is not worn so deep. Again, after this hard mass has dipped beneath the surface, the channel is excavated in softer rocks ; hence the narrow channel and smooth water a mile below the falls. Near the falls, the higher beds of sandstone and the Protean limestone come to the level of the river, and thus cause a wider, shallow channel, and more tumultuous water. Such, simply, I conceive to be the explanation of the variable width of the chasm, and the greater or less violence of the water.

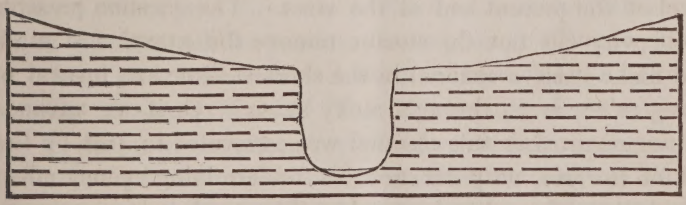
Upon the west bank of the river, at the whirlpool, there is a depression, and a deflection in the course of the river to the right, as will be seen by referring to the map. Standing upon the east bank of the river, this depression has the appearance of having been worn by the eddying current of the stream ; but on farther investigation it proves to be of different origin. During a recent visit, in company with Mr. Lyell, we examined this place, and found it to be an ancient gorge, filled with drift, except a narrow ravine through which a small stream flows into the river. This stream may be traced in a north-west direction for two miles, where it comes to the level of the surrounding country. In one or two places, near the river, the bed of this stream has laid bare the rocks, which proves that they are not excavated so deeply as the bed of the Niagara. From the termination of this ravine, upon

the table land, going in a north-west direction about one mile, we commence descending through another deep gorge, which terminates upon the plateau at the base of the escarpment, at St. Davids. It will be perceived, by referring to the map, that the course of the river before coming to the whirlpool, if continued in the same direction, would lead to St. Davids. From this fact it has been inferred that there is a continuous ancient ravine, filled with drift, from the whirlpool to this place. This most remarkable fact has been cited as a strong objection to the theory of recession by the action of the river upon its own bed. Still, however, I hope to show that its existence is equally an objection to the chasm having been produced by the action of the sea.

If this ravine be continuous from the whirlpool to St. Davids, and existed previous to the excavation of the Niagara channel to Lewiston, it seems natural to suppose that it would have taken that direction. If we suppose that the undermining agency of the ocean, aided by the stream, excavated the Niagara chasm, why would not the same agency have cleared out this ancient ravine? And if it be assumed that the stream had commenced flowing by way of Lewiston, then we require nothing more to account for the commencement of the chasm. The assumption that the sea excavated the present channel of Niagara, does not aid in the difficulty of explaining why the ancient ravine of St. Davids was not cleared out; but on the other hand, the existence of that ravine, filled with drift, is a strong argument that the Niagara did excavate, of itself chiefly, its present channel. For had the sea remained long enough after the filling of this ravine with drift, to excavate that of Niagara, it would have removed a portion at least of it, and have drained the water in that direction. We can scarcely conceive it possible that this ravine could have been filled with drift, by any means, while such a stream as the present Niagara river was flowing through it, and if it has, at any time, been a large water course, there must have been a cessation of the stream during the time of this filling up.

The most rational explanation, and the one most consonant

with existing facts, appears to me to be, that the ravine of St. Davids was excavated by the power of the waves, aided probably by a stream, though it may have been a very insignificant one. That this ravine was formed previously to the period of the drift, and that during this time it became filled with the transported materials to such an extent that the stream afterwards was unable to excavate a channel through the mass. Under these circumstances, the water would find an outlet at the lowest point, into the basin of Ontario; whether that point were over a surface of rock or of drift, and after the channel was once commenced, it would go on deepening, unless some violent change should alter the configuration of the surface. Now there is no evidence of such a change in the Niagara district, and it seems more rational to conclude that the stream, which may have formerly found its way through the ravine of St. Davids, after the filling up of that channel, took the course by Lewiston, that being the lowest point at which it could find a passage to the lower country on the north. It may be necessary, perhaps, to suppose a depression in this direction before the water would flow there; and such a depression may have existed from causes in operation previously, or there may have been an indentation in the edge of the terrace at this place, like those farther east, near Lockport. There appears, indeed, strong reason for supposing that there was a depression in the surface at the place where the river now flows, before the deep channel was excavated; there is a general depression on either side, and a transverse section of the river would present the appearance represented in the annexed diagram.



The recent deposit, forming Goat Island, is upon a surface lower than the top of the rapids, indicating removal of the

surface rock to some extent, before the period of that formation.

I will now proceed to consider, first the objections to the theory that this ravine was produced by the combined action of the stream and the waves of the sea; and next the arguments in favor of the hypothesis that the river has excavated its own channel, or by far the greater portion of it.

Examples are not unfrequent where the closing up of an outlet by drift, has caused the excavation of a new channel through solid rock. Perhaps the best illustration of this fact occurs in the passage of the Genesee river from the upper to the lower valley, from Portage to Mount Morris. The river, flowing from the south as far as Portage, is suddenly turned around to the opposite direction, and then again turns to the north, cutting its channel for about two miles through solid rock, in some parts to the depth of three hundred and fifty feet. At the end of this chasm it emerges into a more ancient valley, and at a point which would communicate with the river at Portage, before its deflection, by less than half the distance which it has required in its present course to reach this place. Now had this short space been occupied by a bluff of rock, we should easily have found an explanation of the reasons why the river did not pursue a direct course. But what are the facts? This shorter space, intervening between the two portions of the channel, is occupied by a deep deposit of drift, rising higher than the surface of the rocks where the river has found its channel. In the process of examination and excavation for the Genesee valley canal it has been found that this drift is of great depth, extending even below the level of the present bed of the river. The question presents itself, why did not the stream remove the gravel and sand, and make itself a channel in the shortest direction, instead of going twice as far through rocky strata? Or if we advance the argument that this channel was excavated in part by the aid of the sea, why did not this undermining agency affect this deposit of sand and gravel? The truth is incontrovertible that many streams have excavated their channels to great depths in rocky strata, long after the ocean left the surface.

Passing lower down on the Genesee river, there are other places where the stream has left the old channel, now filled with drift, and formed a new one, through rocky strata; and finally, at Mount Morris, it emerges into another ancient valley from a narrow gorge bounded by mural escarpments. It would be absurd to assert, that broad valleys, with sloping sides, filled, or partially filled with drift, are of the same age, or due to the same agency, as the narrow, deep valleys or chasms with clean, rocky embankments, and containing no other loose materials than those arising from the adjacent rocks.

Similar examples may be found in the outlets of Seneca and Cayuga Lakes, which flow into Lake Ontario. Now the course of these outlets is not in a direct line north to the lake, but from Seneca it turns to the eastward, excavating its course through the limestone and gypsum beds, between that lake and Cayuga. From all examinations I have made, there appears to be an ancient valley, filled with drift, between the northern end of Seneca Lake and Ontario; and yet, notwithstanding this, the stream has excavated harder materials, and taken a much more circuitous route to Lake Ontario. The same explanation may be given of Canandaigua and the outlets of other lakes.

As an analogous case, we may compare the ravine of St. Davids and the whirlpool, with that of Irondequoit, a few miles east of Rochester. The Genesee river, after leaving the gorge at Mount Morris, flows in the bottom of an ancient valley to within a short distance of Rochester, where it enters a new channel. This channel is narrow, with almost perfect mural banks, and nowhere contains deposits of drift. On the lake shore, about two miles east of the mouth of the Genesee, we find a broad and deep ravine, known as the Irondequoit bay. This ravine is excavated to an unknown depth below the level of Lake Ontario. The Irondequoit creek which takes its rise in the southern part of the county, flows through this ravine for a few miles before reaching the lake. This ravine presents a very different appearance from either that of the Genesee below Rochester, or of the Niagara, and no one could suppose that the present stream had ever excavated such

a channel. At the lake shore, it has a broad opening with sloping sides, and appears much like a bay worn by the action of the sea, while perhaps a stream was flowing in at the same place. It appears very natural to suppose that this may at one time have been the continuation of the ancient valley of the Genesee, which was commenced south of Dansville, and continued northward as the land was upraised above the sea.

Now had the sea ever washed the base of the cliffs at Lewiston long enough to allow of the excavation of this gorge of the Niagara, we should find some evidence of its sojourn there, in the shape of a beach, or rounded pebbles; but we find nothing of the kind. The continuance of a line of coast of sea or lake may be determined comparatively by the character of the materials along its margin; whether they are completely rounded, or still much angular; or if rounded, whether the forms are very much flattened. But in the case before us we find nothing at a greater elevation than the ridge road, or lake ridge, which, from its nature and contained remains, must have been the boundary of an ancient lake.

Other examples might be cited, but these appear to me sufficient as an explanation of causes why the Niagara did not take its course from the whirlpool through the ravine filled with gravel, rather than excavate a new channel from the rock.

We come now to the consideration of the argument that the chasm of Niagara has been worn by the sea, previous to, or during the elevation of this part of the country above its level. In the absence of direct proof, we must resort to analogy, and relying on this mode, we find that all indentations or ravines, excavated in the face of sea cliffs, have a broad or trumpet-mouthed opening toward the sea, and recede abruptly to a point. They never present a long, narrow ravine, of equal width; and when of a length at all approaching Niagara, they have an opening many times broader than this at Lewiston. I might cite numerous examples of ravines excavated by the sea, aided by a stream coming in at right angles, but none of these are of the character of Niagara. In such cases they are broad enough to allow the stream to flow

through the bed, leaving waterworn materials along the sides, monuments of the wearing action of the waves. In the Niagara chasm there are no pebbles, boulders, or gravel; the river occupies nearly the whole width at the bottom, allowing a talus of angular fragments of the rocks fallen from above.

The valley of the Genesee, from Rochester to Dansville, affords a good example of a ravine excavated during the emergence of land from beneath the sea; but this valley is broad, and partially filled with drift, the sides sloping gradually and for the most part covered with deep soil, partially from decomposition and disintegration of the rocks beneath, but principally from transported materials.

The small amount of wearing accomplished by a stream during the period of our observation might incline us to doubt the possibility of any body of water having excavated its channel backwards for a length of seven miles, and to a depth of from three to five hundred feet. But if the period of one life be sufficient to admit of observation proving the *smallest amount of recession*, then it is only requisite that we should carry on the process for an indefinite period, to accomplish the utmost that we require; or, that we extend backward our imagination regarding time, in order to prove what is already accomplished. Now it is attested, within the recorded observations of those residing in the vicinity of Niagara, that the falls have receded within their recollection. If then it is proved that this ravine could not have been excavated by the sea during the emergence of the land, we have only this mode of operation left to account for its formation.

From analogous facts, we learn that it only requires an elevation of the drift, filling up the old channel, to be greater than that of the rocky strata, in order to turn the water in that direction, and cause it to form a new channel. We have only to suppose the ravine, from the whirlpool to St. Davids, filled, as it now is, with drift, to such a height as to prevent the water from flowing in that direction, and the consequence would be, as I said before, that it would seek an outlet at the lowest point along the terrace, which appears to have been in the direction of Lewiston. Here the water

commenced the work of excavation, cutting down the higher strata, and rapidly undermining and removing those below. It is only necessary to refer to the accompanying section, in order to discover what materials the river had to work upon at this period.

It is impossible that there could ever have been a perpendicular fall of the whole height of the cliff at Lewiston, for the limestone at the top, being so much thinner than at the present falls, would soon be broken down by the pressure of the immense body of water precipitated over its edge upon the shale below. It may even be doubted whether the shale would be excavated fast enough to form a perpendicular fall, and it is probable that the water would be projected over a declivity of the upper shale (No. 7,) to the limestone below, which together with the higher layers of the sandstone would form the crest of a second fall. From this again the water would be precipitated as far as the sandstone, (No. 2,) where a third fall would be formed. Thus, instead of a single fall of three hundred and fifty feet, we should have the whole height divided into three falls, at some distance from each other. In consequence of the thinness of the upper limestone, that fall would recede faster than either of those below it; and the middle faster than the lower one. Even under these circumstances, the wearing action would go on much faster than at present. Finally, however, the recession would become less and less rapid, from the thickening of the limestone above; and from this cause, the two lower falls having the same resistance to overcome as at first, would gradually approach the upper, till the whole became one.

At the same time there are other circumstances to be taken into consideration, and among the most important of these will be the dip of the strata and the ascent of the bed of the stream; both together tending to bring the strata down to the level of the water as we progress southward. This fact has also an important bearing upon the rate of recession; for while a hard mass remains at a considerable height above water, with a soft one below, the excavation of the softer one and undermining of the upper hard one, tends to the recession

much more rapidly than if the whole were of uniform character. Thus it must have been that the fall over the sandstone, (No. 2,) receded much more rapidly while there was a considerable thickness of shale below, than when it approached the level of the water. This would happen after the falls had retreated about three miles, or nearly to the whirlpool. At this point the recession would go on very slowly for a long period, for this hard mass, being at the level of the water, would effectually suspend the undermining process. Even at the present time the mass may be seen stretching into the river from either side beyond the other rocks, and at the point where it crosses, producing a fall of eight or ten feet within a few rods.

After this long and almost stationary period at the whirlpool, the recession would again go on more rapidly ; soft materials being presented at the river level to be excavated by the force of the falling water, which would thus undermine the harder mass above.

When the cascade had receded to near its present position, another pause similar to that at the whirlpool would occur, from the approach of the higher layers of sandstone, (No. 4,) and the hard limestone, (No. 6,) to the surface of the water. There are various proofs of this halting, both in the form of the chasm below the present fall, and from the fact that this lower limestone still remains in place ; for it is seen that having passed a few feet beneath the water at the cascade, it supports large fragments of the upper limestone fallen from above.

The conclusion then, seems inevitable, that the river has been the great agent in excavating its own channel, from near the escarpment between Lewiston and Queenston, to the present position of the cataract ; that the recession has been aided by the character of the rocks, presenting alternate hard and soft strata ;—and that the descent was overcome, not by one perpendicular fall, but by several, produced by the successive harder layers. In support of this latter assertion, a single analogous case will furnish stronger evidence than a long argument.

The course of the Oak Orchard creek, in Orleans County, is over the same strata, and furnishes direct confirmation of the succession of falls and rapids, precisely in the manner I have just enumerated. But as this is little known, I will adduce that of the Genesee river, in its descent from Rochester to Lake Ontario.

In consequence of the dip of the strata, or from its absence, the hard, quartzose sandstone (No. 2,) of the Niagara section does not appear in the Genesee river. On entering the river from the lake, we find an open channel for five miles, where the river descends perpendicularly for about one hundred feet from the top of the sandstone, No. 4. The hard limestone layer, or one filling the place of that at Niagara, has retreated a quarter of a mile farther up the river, where it forms a fall of twentyfive feet. This recession of the limestone, beyond the sandstone, is owing to a mass of green shale below it, twentythree feet thick, while at Niagara the same shale is but four feet thick. From this place to the upper fall, about a mile and a half distant, we have a rapid stream. This fall is one hundred and ten feet high, and over precisely the same rocks as the Niagara fall at present, viz. Nos. 7 and 8 of section, the Niagara shale and limestone. The limestone at the top of the fall is much thinner than that at Niagara, in consequence of the less recession into the mass, as well as from being thinner as a whole. We have here a case precisely analogous to Niagara as I have supposed it to have been formerly.

Had there been a quantity of water flowing down the Genesee equal to the Niagara, the upper fall would have been excavated farther backward, and the lower fall, in all probability entirely obliterated, presenting a rapid current from the upper fall to the present site of the Rochester landing. There appears here positive proof that there never has been so large a body of water passing down the Genesee as down the Niagara, and the concurring testimony is to the effect that the wearing action has been far less. The recession of the lower falls at Rochester would add little or nothing to the height of the upper; for the ascent of the river bed, and the dip of the

strata, would cause the disappearance of the whole beneath the water, before reaching that point.

In support of the hypothesis that streams do cut back their channels, we may adduce sufficient evidence. An observation of the last four or five years upon the waterfalls of Western New York, has furnished positive evidence of their recession. Among these may be noticed the falls on Jacock's run, near Genesee, and Fall brook, a few miles further south, both of which have evidently receded, from the undermining of the platform over which the water is precipitated. The amount during this time is very small, but sufficient to be appreciated. The lower falls of Portage furnish another example of recession, where large masses have been removed, the channel deepened, and cut backwards many feet in the space of four years.

Lateral streams flowing into ravines or river courses, furnish the most palpable evidence of the excavating power of water. The channel of Wolf creek, which comes into the Genesee through a perpendicular wall of rock, is a good example of this kind, where the evidence is conclusive that the excavating power is alone due to the stream. The junction of a small stream with the Genesee, on the west side, below Rochester, furnishes another example of this power. This stream has cut its channel through soft shale for fifty feet or more, a bed of limestone eighteen feet thick, a bed of shale of equal thickness, and below this another bed of limestone nearly equal to the upper one. Many more examples of a similar kind might be named, on the Seneca and Cayuga lakes, and their valleys continued to the south.

A remarkable fact connected with these lateral water courses is that their dimensions bear some proportion to their present quantity of water. And although the actual quantity flowing in any stream may seem insufficient to excavate its bed, yet I believe, generally, the largest streams will be found in the largest ravines, and the small lateral streams have always a proportionately smaller channel. If in any case we find the stream débouching into the lake, river, or valley, through a chasm with nearly perpendicular sides, and little or no wider

than it is farther up the stream, we may infer that the action of the sea has had nothing to do with its excavation.

So far as our present knowledge extends, regarding the mode of excavation by streams, conjointly with the action of the sea upon cliffs, I consider the question regarding Niagara as settled; both by the analogy thus afforded, and by the examples of streams passing over the same succession of rocks; as the Oak Orchard creek and the Genesee river. The narrowness of the chasm from Lewiston to the site of the present cascade, the nearly perpendicular sides, and the absence of drift within its banks, are strong negative facts in support of the proposition. The evidence that the falls are now receding, and the incontestible proof that they have receded considerably since this region has been inhabited, are positive facts in favor of the hypothesis. Within four years, a large triangular mass has disappeared from the top of the American fall, and the outline is becoming more curved. At several successive periods, large masses have fallen from the table rock, on the Canada side, which has considerably changed the outline of the fall.

There is still further evidence that the waters of the Niagara river have once extended much nearer to the brow of the escarpment than they do at present. The nature of this evidence I pointed out in my report on the fourth Geological District of New York, in 1838, pages 271, 272, and 273. At that time, I was not aware that the same phenomena had before been noticed, though I have since learned that the existence of fresh water deposits in Goat Island had been mentioned some years previous. Whether the important inference had been deduced from this fact or not, I do not know.

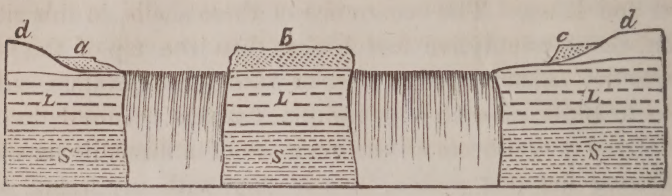
Goat Island stands upon the top of the precipice separating the two falls; it is formed by the accumulation of gravel, sand, and clay, upon the surface of the limestone, and is evidently a portion of a once much more extensive deposit. Upon the southern side of this island, where there is an escarpment, the thickness of the mass is about twentyfive feet. The upper half of the deposit consists of coarse gravel and sand, with abundance of fresh water shells of the genera

Unio, Cyclas, Limnea, Planorbis, Valvata, and Melania; the same both in genera and species as those now inhabiting the river and lakes. The occurrence of these shells, in this situation, about twentyfive feet higher than the top of the fall, proves the existence of a river or lake at an elevation sufficient to allow of such a deposition, for this accumulation of shells and gravel bears all the evidence of a fluviatile deposit.

During the past season, in company with my friend, Mr. Lyell, I re-examined this region, and upon the east side of the river, in a terrace about the same elevation as Goat Island, we discovered the Cyclas, Valvata, &c. which had been thrown from an excavation made several years since. At the same place, a tooth and some bones of the Mastodon were discovered eleven feet beneath the fluviatile deposit. Farther northward, and more than half a mile north of Goat Island, in another excavation, we discovered similar shells. We also noticed the continuation of this terrace, or one about the same elevation, as far north as the whirlpool. We did not search for shells in it at this place; but from its character and position there can be little doubt but it is a continuation of the same deposit, and probably will be found to contain the same shells. Now in order to raise the water of the river to sufficient height to make this deposit, it would require a barrier for the water at some distance north of the whirlpool. On the other side of the river a similar terrace exists, but this I have not particularly examined.* Now these banks or terraces on either side of the river, and that of Goat Island, are clearly not deposits made in this form, but the remains of a once much more extensive one. During the time of its deposition the river occupied this valley, having its barrier far towards Lewiston. In the bed of this expanded river or lake, much as it now is above the rapids, this deposit was made, covering the whole extent; but from the wearing back of the fall it has been carried off, the margin only being left on either side, and a small portion of the central part forming Goat Island. The following diagram will exhibit the posi-

* Mr. Hayes speaks of the terraces on both sides of the river, as containing fresh water deposits. Amer. Journal of Science, Vol. XXXV, No. I.

tion of this fresh water deposit. It is a cross section of the river at the falls.




*a*. The terrace with shells on the eastern side.
*b*. Goat Island. *c*. The terrace on the Canada side.
*d*. The ancient drift. L. Limestone. S. Shale.

From its present position, it seems to have been a continuous deposit, the greater part of which has been removed. The mode of its formation can be well illustrated by referring to Fig. 1, which is intended to represent what is now going on above the rapids, in the broad expansion of the river. *a*. *a*. represents the fluviatile deposit made by materials brought down by the current, and doubtless mingled with a large accumulation of shells of Unio, Melania, Anculotus, &c. as these shells are abundant above the falls, and large numbers of the shells of Uniones are constantly brought down the rapids during the summer season.

The single terrace containing shells is not the only one, for on the eastern side, at lower elevations, there are in succession two others, which seem to be remains of the deposit in the river bed, as it successively excavated its barrier to the north, and receded towards its present position. For the greater part of the distance from the falls to Black Rock, on the eastern side there is a terrace or bank a few feet higher than the river, which may have originally limited its waters when it stood at the level indicated by the fresh water deposit of Goat Island. Near Black Rock, and bordering the valley of the Tonawanda, there is a terrace some twenty feet higher, which appears to have been the boundary of the river or lake at a still earlier period; but with these we have, at present, nothing to do. The existence of the fluviatile deposit of Goat Island, and at the same level on the eastern side of the

river, requires for its elucidation the existence of water standing at a level somewhat higher, in order to allow of the deposit being made in the bed of the stream. To accomplish this, a barrier is required further north than the whirlpool, and about the height of the surface of limestone between this and Lewiston. The occurrence of successive terraces below this one, proves that the drainage to the present point was not effected suddenly.

There is another fact which should be noticed, as proving the existence of a current from south to north, during the deposition of the materials forming Goat Island. The pebbles, at least large numbers of them, are of the limestone of Black Rock, and the harder layers of the saliferous formation, like the rock in place at the upper end of Grand Island. The surface of the rock, on which the deposit forming Goat Island is made, is smoothed and scratched, as are the surrounding surfaces both in the rapids and on either bank of the river. The deposit is of greatest thickness towards the fall, and thins entirely out at its eastern extremity.

There is another indentation on the eastern bank of the Niagara, below the whirlpool. This has been cited as a case where the small stream coming in, is insufficient to account for such an excavation.* It occurs at the junction of Bloody run and the river, and bears the strongest evidence of having been produced by the common agents, frost and water. The wearing action of the stream alone is probably insufficient to produce this short ravine, which extends a few rods back from the margin of the river bank; but when we take into consideration the fact that the water penetrates all the fissures of the rock, and then, during fall and winter, expands by freezing, we shall find means of explaining the mode of operation. At the falls, the recession is by the undermining and breaking down of the upper masses; the action of frost is not to be taken into consideration, as the water never freezes. Now I consider it as an established fact, that small streams, which freeze during winter, will excavate their beds more rapidly

* Am. Journal of Science, Vol. XXXV, No. I.

in proportion, than large bodies of water, which never freeze. It appears to me that the indentation at Bloody run is not greater than might be expected to have taken place while the main channel receded to its present position.

Whatever facts and arguments may be advanced to prove the existence of phenomena indicating the former action of the sea in excavating the Niagara channel, and whatever objections may be advanced for or against other theories, I am fully of opinion that the existence of the falls and the Niagara river, in their present position, is of very recent date, geologically speaking. I cannot resist the belief that at some previous period the waters of the upper lakes were discharged into Ontario at its western extremity, and that subsequently, from causes which at present I have not facts sufficient to explain, the course was changed, and the outlet made through Lake Erie. Previous to this time, there may have been a small stream flowing in the direction of the present Niagara.

We come now to consider the future recession of Niagara falls, and its consequences. This is a subject on which many speculations have been hazarded, but no one appears to have undertaken the calculation with a full knowledge of the geology of the district, or to have taken into account the many disturbing influences. At the present time, the cliff over which the water is precipitated, is nearly equally divided between thick bedded limestone and soft, disintegrating shale. It is by the action of the spray from the falling water upon the shale, undermining and leaving the limestone unsupported, which falls down by its own weight, that the falls recede from their present position. Now if we believe the statements of those who have resided at the falls, the recession has been about fifty yards within the last forty years; but from all the data I have been able to obtain, it appears to be much too great an estimate; indeed, it is extremely questionable if the fall has receded as many feet within that time. The central portion of the Canada fall recedes more rapidly than any other part, for here the greatest force of the river is exerted. We know, likewise, from the testimony of all residents at this place, that the American fall is becoming more curved in its

outline, whereas formerly it was nearly in a straight line. The successive descent of large masses of limestone, and the still continued overhanging of the table rock, prove very conclusively the unremitting action of water and air upon the shale below.

In the absence of established landmarks, we are compelled to leave the rate of recession unsettled for the present; and the only mode by which this can be determined accurately is, by a systematic survey and triangulation of the form of the cascade, and the establishment of permanent marks of reference for future observers.

Leaving out of view the time or rate of recession, we have sufficient data to establish with certainty the future changes which will supervene, allowing the recession to go on as it is now doing. The lower half of the rock at the cascade, or about eighty feet, is of soft shale, the limestone above being of equal thickness; higher still is about forty feet of thin, bedded limestone, forming the rapids. These different rocks are represented in the section as 7, 8 and 8′, respectively. Now these beds dip to the south at the rate of about twenty-five feet in the mile, and the declivity of the bed of the river is about fifteen feet in the mile, from the falls to Lewiston. It follows, therefore, that as the falls recede, there will be a less amount of shale above water, owing to the dip, and to this must be added the amount of declivity in the river bed, both together making forty feet. So that when the fall has receded one mile, the surface of the water will stand at *k.*, or a point in the shale half way between the present surface of the water and the bottom of the limestone. Going on at this rate for another mile would take away from the fall forty feet more of the shale, so that the surface of the river would stand at *p.* or the base of the limestone.

The cataract would then have a solid wall of limestone to wear down, the river beneath protecting, in a great measure, the undermining action upon the shale. During this time, and at the end of the first mile, the falls would have arrived at the present site of the commencement of the rapids, and thus about forty feet more of limestone would be added to

the height; unless from its thin bedded character it continued to recede faster, and thus continue a rapid. In this case, there would be a fall of one hundred and twenty feet at the end of the first mile (*i. k.*); and one of eighty feet (*o. p.*) at the end of the second mile.

At this period, then, we are to contemplate the cataract of Niagara as having receded two miles, the shale having disappeared beneath the river, and the cascade presenting a solid wall of limestone eighty feet high, and a rapid of forty or fifty feet (*o. m.*) beyond. The recession would then go on very gradually, and so soon as masses from this cliff have fallen down to fill up the river bed, as they inevitably will in a great measure, then the base will be protected so effectually that little influence will be exerted by the force of the water. Eventually, however, the cliff will be broken down, and huge fragments piled up below, until the cataract will be nearly lost amid them. This state of things will continue for a long time, the height gradually diminishing, till the river has cut its way back for two miles further, when there will be no thick bedded limestone above water, and the higher beds will form a rapid as before.

This point of meeting, between the surface of the river and the top of the thick bedded limestone, will be about one hundred feet lower than the summit of the present cascade, and as there will be forty feet of rapids in the thin bedded limestone within a short space, as there now is, it follows that there will be added to the descent of the river beyond the rapids, one hundred feet more than at present, as the surface of the limestone has dipped to that amount. The whole fall in the river at that time, from Lake Erie to the point of junction between the limestone and water below the rapids (*h. o.*), will be about one hundred and sixty feet. The distance between this point and Lake Erie is occupied by nearly uniform soft layers, and after a partial wearing down of the limestone forming the rapids, the descent will be equally distributed over the whole extent of sixteen miles, giving a uniform declivity of about ten feet in the mile, or one third less than the present declivity in the bed of the river from the falls to

Lewiston. From the nature of the bed of the river for fifteen miles below Lake Erie, it may be doubted whether this rapid descent along the whole distance would be continued; for the stream, having no heavy blocks of rock to remove, would keep its channel clear with a far less declivity; and should this prove the case here, we might still have a fall of a few feet, at the outlet of Lake Erie, over the limestone succeeding the saliferous group.

Whether such a fall would occur at the outlet of Lake Erie, depends on the solution of the problem regarding the acquired declivity in the bed of the river below Lake Erie. Whichever way it may occur it will make no material difference in the great result, which will be either a continuous rapid stream from Lake Erie to Lewiston, or a rapid stream with a fall at the outlet of Erie. If present causes continue to operate as now, such will be the consummation, the finale, of the grand cataract of Niagara.

It is unnecessary here to follow on this recession gradually from the outlet of Lake Erie to the final drainage of a great portion of its waters. The views which have been entertained of the sudden drainage of this or any of the upper lakes, and a deluging of the country on the north and east are no longer considered as tenable by any one, and even if Lake Erie could be drained suddenly, it would cause no deluge of any importance. If the whole lake were at once placed upon Lake Ontario, it would only elevate its surface by about one hundred and fifty feet, so that its extent would scarcely exceed the limits of the ancient lake ridge, and the outlet would still be the valley of the St. Lawrence.

In calculating the future recession of Niagara falls, there are many disturbing influences to be considered. At the present time, by means of the Erie and Welland canals, large quantities of water, which formerly flowed over the fall, are returned to Lake Ontario by other than the natural channels. The Illinois canal, at the southern extremity of Lake Michigan, will drain a large amount of water in that direction, which will find its way to the ocean through the Mississippi river and Gulf of Mexico. Extensive improvements have been

contemplated at the falls, and the erection of manufactories, by which great quantities of water from above the rapids will be returned to the Niagara channel below the falls. Thus far the country supplying water to the upper lakes has been but little changed by the hand of cultivation, the primeval forests still clothe the surface, and evaporation to a great extent is prevented. This cannot always remain so; the advancing settlements will yet penetrate even the wilderness bordering Lake Superior, and the opening of the surface to the influence of the sun's rays will greatly diminish the supply of water flowing into the tributaries. These causes will sensibly diminish the quantity passing down the natural outlet; and the mighty Niagara, the "*Thunder of Waters*," is destined to be at certain seasons but a diminutive representative of its former grandeur.

Note. Since writing the foregoing paper, I have referred to some notes and correspondence with Mr. Roy, Government Engineer at Toronto, U. C. From levels which he has made from Lake Ontario to the Queenston heights, at several places, he says the crest of the terrace constantly declines going westward from the river, while the base continues at the same elevation. This fact is opposed to information I had before received, and to the general belief. If this be substantiated, and I have every reason to believe the statement, it may materially alter the reasoning in regard to the former recession, of the falls, and the manner in which the chasm has been excavated.

From the Niagara river there is a declination of the crest of the terrace eastward, so that at Rochester its summit is about sixtyfive feet below the level of Lake Erie; giving in this direction a descent of about one hundred feet in eighty miles.* I have no data for determining the rate of declination westerly, but whatever it may be, it proves the course of the Niagara to be upon or near the highest part of this terrace. If this inequality of the surface was produced by some force after

* See New York Geological Reports.

the strata became consolidated, there might have been produced a rent in this direction, as in the diagram which represents a transverse section.

This may have been the first cause of directing the water in its present channel, which was afterwards widened by the river. There seems some reason to suppose this may have been the case, from the general direction of the chasm, being at right angles with the strike of the strata. If this be true, however, the fissure must have been extremely narrow, and still have left to the river the work of excavation, though under very different circumstances. The reasoning in regard to the existence of a depression previous to the excavation of a deep channel, will still hold true, as well as that regarding the fresh water deposits, and the terrace extending to the whirlpool. The future recession of the cataract cannot be affected in any manner by this fact, for if such a rent ever existed, it seems not to have extended as far as the present site of the falls, for all the testimony is to the effect that the process of retrogression goes on by the action of the water upon the shale, which undermines the limestone. If there was a fissure in the course of the Niagara, it did not reach so deep as the bed of the river, for it seems quite certain that the thick bed of sandstone (No. 2, of section,) has never been excavated very deeply below the present surface of the river.

If these views regarding the elevation of the terrace are found to hold true, it will aid in establishing the opinion before expressed, that the present channel of Niagara is of recent date. I have long believed that the former outlet of the great Lakes was by the western end of Lake Ontario, though I have not been able to make investigations to the extent desired in order to establish that opinion.

The period when the disturbance of the strata took place, is one of great importance, and may aid in determining the comparative age of the Niagara channel, and the period of the drift. That the former was subsequent, however, does not admit of doubt. I am not aware how far the terrace continues to decline westward from the Niagara river, but it is quite certain that the limestone rises before going as far west as the

head of Lake Erie; for we find crossing this lake near its western extremity, an anticlinal axis which extends northward into Canada, and southward entirely across the State of Ohio. Now this may have happened at the same period as the disturbance or uplift, further east, and the production of this western axis may have resulted in turning the course of the outlet, and the formation of the Niagara river; but more facts are required before any speculations can be offered upon this subject.

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